Fishery Data Series No. 98-37

Radio Telemetry of Arctic grayling in the Delta Clearwater River 1995 to 1997

William P. Ridder

December 1998

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 98-37

RADIO TELEMETRY OF ARCTIC GRAYLING IN THE DELTA CLEARWATER RIVER 1995 TO 1997

by

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ABSTRACT

In 1995 and 1996, 110 adult Arctic grayling *Thymallus arcticus* with implanted radio transmitters were released at their summer feeding area in the Delta Clearwater River, a spring-fed tributary to the Tanana River in interior Alaska. The fish were tracked from aircraft and by boat for one year after implanting to locate overwintering and spawning areas and to estimate fidelity to the Delta Clearwater River for summer feeding. The majority of fish overwintered within a 115 mi reach of the Tanana River. Spawning areas were found in eight streams up to 72 mi distant from release. The greatest proportion of radio tagged fish spawned in the Goodpaster (59%, SE = 7%) and Volkmar (20%, SE = 6%) rivers. After spawning, 98% (SE = 3%) of live fish returned to the Delta Clearwater River for summer feeding. A radio tag shedding rate of 25% (SE = 9%) is estimated from recaptures of 24 radio-tagged fish one to two years after release.

Key words: Arctic grayling, *Thymallus arcticus,* radio telemetry, spawning, overwintering, fidelity to summer feeding area, tag shedding, mixed stocks, Tanana River, Alaska.

INTRODUCTION

The Delta Clearwater River (DCR) is a 21 mi long spring-fed system located 110 mi southeast of Fairbanks and 14 mi northeast of Delta Junction in the middle Tanana River drainage (Figure 1). It is the largest and most accessible spring-fed system entering the Tanana River and provides quality feeding habitat for Arctic grayling *Thymallus arcticus*. The river's Arctic grayling fishery is unique among the Tanana River drainage's road accessible fisheries because it is comprised of fish originating from a number of donor 'stocks' that use the DCR only for summer feeding (Reed 1961, Tack 1980, Ridder 1991). Immigration to the DCR begins in April with juvenile fish, followed by adults, and lasts into June. Emigration begins in August and is complete by December.

Since 1953, the river has offered a small but productive and popular Arctic grayling fishery known for its high catch rates, large Arctic grayling, and pristine water quality. The fishery harvested predominantly adult fish of ages 5 and older and had historical harvests that ranked in the top five Arctic grayling fisheries in the drainage. Annual harvests prior to 1987 exceeded 5,000 fish but have fallen to 1,640 fish through 1996 (Mills 1978-1994, Howe et al. 1995-1997). This decline in harvest and in drainage wide abundance indices led to restrictive regulations enacted in 1987 for the DCR and other fisheries in the drainage. Regulations included the imposition of a catch and release season until the first Saturday in June, a 12 in total length (TL) minimum size limit, a no bait restriction, and five fish daily bag and possession limit (limits were 10 fish daily and 20 fish in possession prior to 1977 and five daily and 10 in possession, respectively, through 1986). Catch-age (Deriso et al. 1989) abundance estimates in 1994 (Clark and Ridder 1994) that estimated a population decline of 8,000 fish between 1977 and 1990 and an average exploitation of 34% precipitated a three year program in 1995 to estimate the dynamics and document recruitment sources of the population. Initial estimates showed a continuing decline in abundance and resulted in further restrictions to the fishery. A two fish bag and possession limit was imposed in July of 1995 and the fishery became catch and release in July of 1996.

This study presents the results of one component of the 1995 program, the documentation and qualification of the contribution rates of the various stocks or 'donor' streams that comprise the population of the DCR. Radio telemetry techniques were used to examine

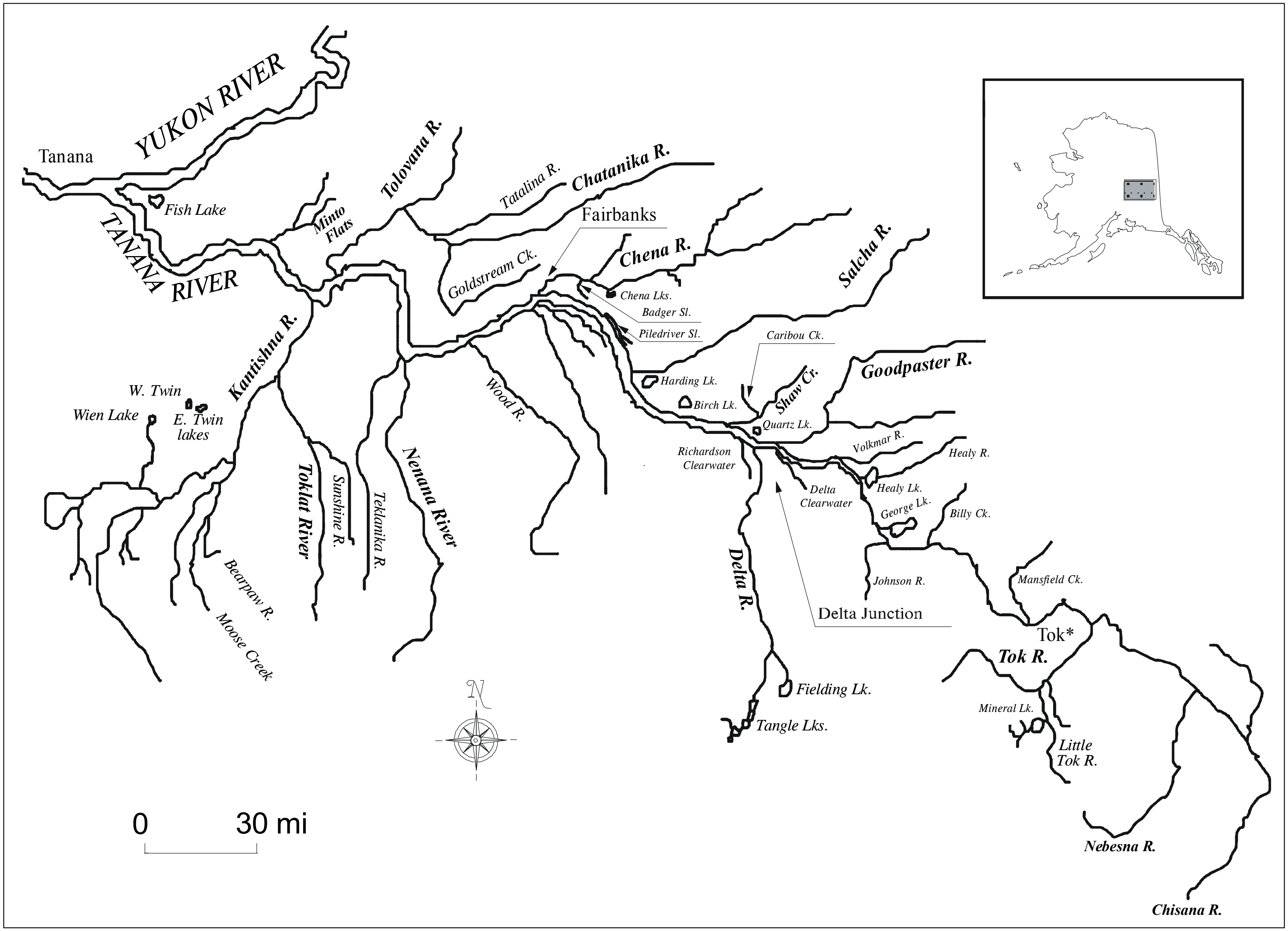

Figure 1.-The Tanana River drainage.

annual movements of adult Arctic grayling residing in the DCR in July of 1995 and 1996. The study had the following assumptions:

1. the summer feeding period extends from 1 July through 31 July;
2. the distribution of adult Arctic grayling in the DCR during the summer feeding period is closed to emigration and immigration;
3. small adult fish (<330 mm FL) behave similarly as the larger adults which will carry the radio transmitters;
4. adult fish home to natal areas for spawning; and,
5. the rate of tag failure plus total mortality of implanted fish does not exceed 50%.

The goal of the study was to identify the major donor stocks to the DCR fishery and to investigate the fidelity of Arctic grayling to the DCR for summer feeding. Fidelity is necessary to test the hypothesis that the DCR population can be considered as a unit of stock necessary in the use of catch at age analysis (CAGEAN) in modeling the population.

The specific objective (Job No. R-3-2c in Projects F-10-11 and 12) was to:

> estimate the proportion of large Arctic grayling ($\geq$ 330 mm FL) implanted with radio transmitters that were released in the DCR in July and located alive in at most six spawning streams in May.

In addition to this objective, estimates of fidelity to summer feeding areas and locations of overwintering areas are presented.

METHODS

Radio telemetry was used to track 110 Arctic grayling that were implanted with radio transmitters in the DCR; 55 fish were tagged on 20-27 July 1995 and 55 fish on 24-27 July 1996. The objective was to distribute the radio tags evenly along the lower 14 mi of river where fish were present. However, capture method and time constraints prevented an equal distribution in 1995. Boat-mounted electrofishing captured 34 fish from river miles 5-14 with the majority, 27 fish, coming from river miles 12-14. Hook and line was used to capture 21 fish from river miles 7-3 with the majority, 13 fish, from river miles 7-5 (Table 1). Fish were held for one to two days in pens located at river miles 12, 5, and 3 prior to implanting and release to reduce the incidence of multiple captures. In 1996, fish were captured along the same 14-mile reach by hook and line during the second event of a mark-recapture experiment and held in seven pens located roughly every 2 mi along the reach (Table 1). Fish were held at least one day prior to implantation and were released within 2 mi of their capture location. Radio implanted fish in 1996 were near equally distributed along the river.

Radio transmitters were manufactured by Lotek Engineering Inc (Model FSM-6) and each had a unique frequency (Appendices A1 and A2). The transmitters produced 41 beeps per minute with a guaranteed life of 328 days (80% of the expected life of 410 days), which suggested that transmitters would last at least to the third week of June. The

Table 1.-Catch and release locations of Arctic grayling implanted with radio transmitters, Delta Clearwater River, July 1995 and 1996.

	1995		1996	
River Mile	Catch	Release	Catch	Release
14-12	27	27	8	8
12-10	3	0	8	8
10-9	3	0	6	6
9-7	1	0	8	8
7-5	13	20	7	7
5-3	8	8	9	9
3-1	0	0	9	9
Total	55	55	55	55

transmitters were 56 mm long and 11 mm in diameter, had an air weight of 8.9 g, and a plastic coated flexible whip antenna 31 mm long. The 2% rule (Winter 1983: transmitter weight not to exceed 2% of the fish's weight in air which in this case was 445g) was used in selecting fish for surgery. Based on the length weight relationship found for DCR Arctic grayling (logW = -4.997 + 3.035*log L; unpublished data), the 2% rule dictated fish with a minimum length of 330 mm FL. In 1995, radio implanted fish ranged in fork length from 342-444 mm and in weight from 456-1,144 g (Appendix A1). In 1996, implanted fish were 353-440 mm FL and 465-961 g (Appendix A2). In 1996, radio implanted fish were also tagged with Floy FD67 anchor tags.

Fish were anesthetized with MS-222 and transmitters placed in the coelomic cavity through a 20-30 mm incision anterior to the pelvic girdle following the surgical procedures described by West et al. (1992). An exception to the procedure was that 3-4 stitches, instead of 6-7 stitches, were used to close the incisions and these were followed by an application of "Vetbond", a cyanoacrylate tissue adhesive. Surgery times averaged 6 min. After surgery, each fish was allowed to fully recover from the anesthetic in a tub of fresh water prior to release. No mortalities occurred during surgery or the recovery period and fish appeared to be in good condition at release.

TRACKING

Locations of Arctic grayling tagged in 1995 were determined from 13 aerial surveys and two boat surveys conducted from October 1995 through August 1996 (Table 2). Locations of fish tagged in 1996 were determined from seven aerial surveys and two boat surveys from August 1996 through July 1997 (Table 3). Flights employed two different aircraft and antennae configurations. The Piper PA 18 used one 'H' antennae while the Cessna 185 used two 'H' antennae. On both aircraft, the antennae were oriented forward and slightly down. Both aircraft were equipped with a Telonics TR-2 receiver coupled with a TS-1 scanner. On flights with the Cessna, two observers each monitored 27-28 frequencies on the receivers during the first day of a flight while usually one observer monitored the 'leftover' frequencies on the second day of a flight. Five different personnel acted as observers on the surveys: two observers were new to radio tracking and were teamed with an experienced observer on two flights in each year. Flights were directly over stream courses as much as practical at 600-1,000 ft above ground level and 90–110 mi/h for the Cessna 185 and 50-80 mi/h for the PA-18.

Additional surveys by boat were conducted in both years in the DCR and Goodpaster River in an effort to determine if those transmitters that had not moved (greater than 1 mi) were still associated with live fish. Boat surveys used the same receiver and scanner as aerial surveys with one 'H' antennae oriented forward and mounted 6 ft high.

Areas and number of transmitters searched varied among the flights in both years especially during May and later surveys. Surveys concentrated on the Tanana, Goodpaster and Delta Clearwater rivers from October to May and then expanded to include at least one survey of all tributaries of the Tanana River from above Billy Creek at river mile 425 to the Chena River at river mile 218 (Figure 2). All transmitters were searched through April of each year (Tables 2 and 3).

Table 2.-Information associated with each tracking occurrence, and results for Arctic grayling radio-tagged in the Delta Clearwater River in 1995.

Survey		Area		Number of Tags		
Date(s)	Method	Searched	Hours	Searched	Found	Not Found
10/17/95	Cessna 180	All	4.3	55	54	1
12/7-8/1995	Cessna 180	All	6.5	55	52	3
3/11/96	Cessna 180	All	5.0	55	51	4
4/9/96	Cessna 180	All	5.2	55	47	8
4/29-5/3/96	Cessna/Piper	All	9.3	53	44	9
5/2/96	Boat	DCR	4.0	6	6	0
5/6-5/7/96	Cessna/Piper	All	8.7	42	30	12
5/13-5/15/96	Cessna/Piper	All	8.6	51	41	10
5/28-5/30/96	Piper	All	8.0	52	34	18
6/11-6/12/96	Cessna/Piper	All	7.5	37	26	11
6/17/96	Cessna 180	All	5.0	22	16	6
7/3/96	Cessna 180	Selective	4.4	20	14	6
7/5/96	Boat	Goodpaster	5.0	10	9	1
7/16/96	Piper	Selective	2.1	20	6	14
8/15/96	Piper	Selective	3.0	16	1	15

Table 3.-Information associated with each tracking occurrence, and results for Arctic grayling radio-tagged in the Delta Clearwater River in 1996.

Survey Date(s)	Method	Area Searched	Hours	Number of Tags Searched	Found	Not Found
8/12,8/15/96	Piper	DCR, GPR[a]	3.3	55	45	10
10/2-10/3/96	Cessna 180	All	7.5	55	51	4
12/18,12/24/96	Cessna 180	All	7.7	55	53	2
5/1-5/2/97	Cessna 180	All	8.4	55	46	9
5/8-5/9/97	Cessna 180	All	7.2	27	18	9
5/21-5/22/97	Cessna 180	All	8.5	55	49	6
6/5-6/6/97	Boat	DCR	5.5	46	26	20
6/23/97	Cessna 180	GPR,VOLK[b]	4.0	22	15	7
7/19/97	Boat	GPR	5.5	7	7	0

[a] GPR is Goodpaster River.

[b] Volk is Volkmar River.

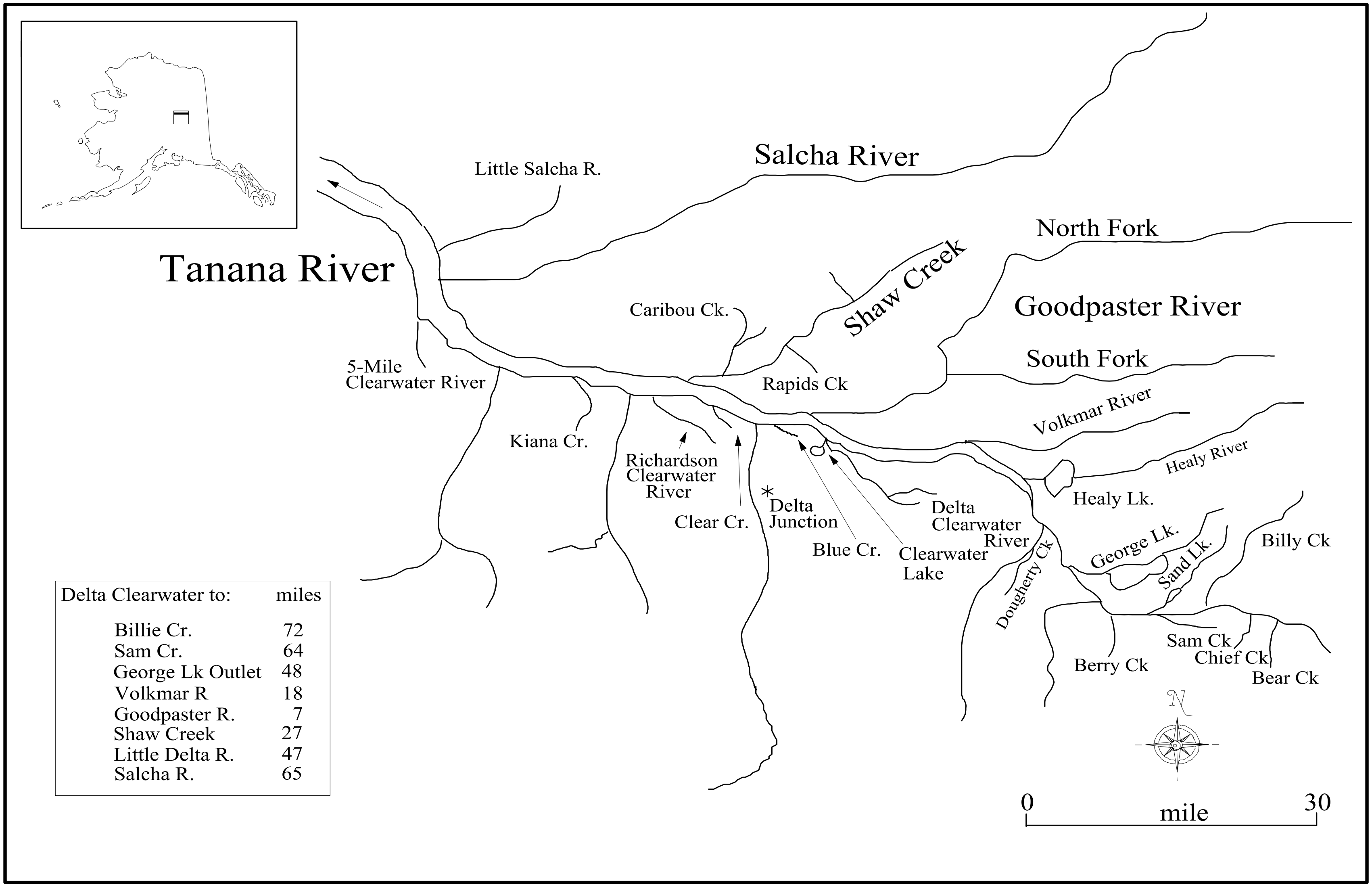

Figure 2.-Locations searched during aerial surveys for radio-tagged Arctic grayling 1995 through 1997.

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Location of a (fish) transmitter during boat and aerial surveys was determined by monitoring its pulse intensity for the 'null point', which is a noticeable decline in pulse intensity when passing directly over the transmitter. The location of the null point was then recorded with a GPS (global positioning system) receiver as latitude and longitude coordinates on a field form. General locations in river mile were also recorded. In most instances, two or more passes along a stream reach were necessary to determine the location of a specific transmitter. For some frequencies during the flights, pulse intensity was either erratic (being dependent on the direction of the flight), weak with ambiguous null points, or severely corrupted by static. In these situations, determination of location was somewhat arbitrary.

Determinations of mortality are necessary in qualifying the tracking results especially regarding an estimate of fidelity. This study addressed mortality as inferences from tracking results. If fish did not move between three or more surveys and especially if these surveys spanned times of expected movement, i.e. fall and spring, then the fish was presumed dead or had shed the tag. In this study, those transmitters that remained in the Tanana River after spring ice-out were intuitively associated with a dead fish or a shed tag. At this time, the river becomes highly turbid with glacial run-off and inhospitable to a sight feeding fish such as Arctic grayling. Also, fish that moved from the Tanana River into tributaries during May were considered to have done so for the purpose of spawning regardless if they were later determined as dead. For those fish that remained in tributaries after the spawning period, or which never left the DCR, mortality determinations were based on boat surveys and the calculation of straight-line distances (SLD) between successive survey locations (Appendix A3). During boat surveys of the Goodpaster River and DCR, transmitters were located to within 5 ft by successively removing components of the receiver (first the antenna, then the antenna lead). The transmitter was associated with a dead fish if one or more of the following occurred: the transmitter was physically found, no large fish were observed in the vicinity, or no audible change in pulse intensity occurred after disturbance of the area. SLD's were necessary for inaccessible fish in Shaw Creek and the Volkmar River and were calculated from lat-long coordinates transferred to a computer spreadsheet as

$$SLD = \sqrt{}\,((lat_i - lat_{i-1})*111\text{ km})^2 + (long_i - long_{i-1})^2 \qquad (1)$$

where: lat_i = the latitude of the *ith* location in degrees;

$long_i$ = the longitude of the *ith* location in degrees;

70 mi the distance of one degree latitude; and,

30 mi the distance of one degree longitude near the 64th parallel.

The location coordinates determined from the air are not precise. Evenson (1993) determined that actual river locations of radio-implanted burbot were within 0.3 mi (0.5 km) of locations determined from the air using the same equipment as this study. (Peckham and Ridder 1979) determined locations of five radio-implanted Arctic grayling in the Chena River from aerial surveys were from 0-0.6 mi from those determined on the ground with an average maximum difference of 0.4 mi (SD = 0.1 mi). In this study, the 1995 boat survey of the Goodpaster River located nine transmitters and recovered two transmitters 2 days after an aerial survey. SLD's for these transmitters ranged from 0.0-0.8 mi (Appendix A3). The recovered transmitters both had SLD's of 0.7 mi. For the purposes of this study, fish with SLD's of less than 1.4 mi had not moved.

At the conclusion of the experiment, those coordinates associated with fish located in tributaries during May surveys were plotted on United States Geological Survey topographical maps (1:63,360 scale). One-mile increments were also plotted on the maps with a planimeter and plotted locations were estimated as the xth mile upstream of the tributary's mouth.

Four surveys in May 1996 and three surveys in May 1997 were flown to locate spawning areas and began near or on 1 May for both years. The surveys were then flown approximately every 7 days (Tables 2 and 3). The first survey in both years happened to coincide with the beginning of ice-out in the tributaries within the study area (Figure 2). The Goodpaster River ice began breaking up the last week of April in 1996 and 1997. The river was ice free on 9 May 1996 and 4 May 1997. Tack (1980) stated that Arctic grayling commence spawning at 4°C soon after ice-out. Beauchamp (1990) and Ridder (1989) noted that spawning commenced rapidly with warming temperatures; the duration of spawning activity ranges from 6 to 16 days. Spawning fish were collected in the Goodpaster River from 9-16 May 1996 and 6-11 May 1997. Thus in this study, fish that moved into tributaries on any May flight were considered to have spawned there. Spawning location data presented in this report was a compilation of all May flights with one exception. Those fish that left tributaries and returned to the DCR within the May flights are presented as being in their spawning tributary. Spawning distributions in the tributaries were determined as the furthest upstream mile in which the fish was located. Overwintering locations were inferred from a December flight.

All data pertaining to age, length, sex, tag numbers, colors, and tag losses (from previous studies), release location, transmitter frequencies, and finclips were recorded on mark sense forms and transformed into an electronic (ASCII) data file, U0060ld5.dta. Latitude and longitude coordinates of radio tags found during aerial surveys were transcribed to a spreadsheet, Lat_Long.xls. These data files were archived in file U0060aa.zip at the Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

RESULTS

Ninety-seven of the 110 tagged fish (88%, SE = 3%) were located to the end of the study, 85% (SE = 5%) of the 1995 tags and 91% (SE = 4%) of the 1996 tags. Forty of these fish (52%, SE = 5%) were considered alive. Of the 13 fish that were not located, one fish was never found and the rest located only to the overwintering survey. The loss of these fish was likely the result of a failed transmitter (due to either quality or predation) or the fish was outside the search area.

The distribution of radio tag releases was significantly different between years ($\chi^2 = 17.39$, df = 3, $P < 0$; Table 4). However, this distribution did not result in significantly different fates between areas of release within or between years ($0.08 < P < 0.94$, Table 4).

OVERWINTERING AREAS

Overwintering areas were inferred from the December survey without mortality considerations and were similar between years (Table 5). For 1995 tags, locations spanned 82 mi of the Tanana River drainage from below the Little Delta River to 10 mi above the Volkmar River (Figure 3). For 1996 tags, fish were located along 105 mi of the drainage from Moose Creek near Fairbanks to 8 mi above the DCR (Figure 4). In both years, the Tanana River was the major area

Table 4.-Contingency tests on three distributions of radio implanted Arctic grayling released in the Delta Clearwater River upstream (US) and downstream (DS) of river mile 9 in 1995 and 1996.

At release:

River mi	1995 Tags	1996 Tags
14-12	27	8
12-9	6	14
9-5	14	15
5-1	8	18
	$\chi^2 = 17.39$	
	Df = 3	
	P = 0.00	

At overwintering, December:

	1995 Tags		1996 Tags		Both	
Areas[a]	US	DS	US	DS	1995 Tags	1996 Tags
GPR	15	4	6	5	16	17
DCR+Tan1	7	9	7	10	19	11
Tan2+3+4	10	9	8	17	19	25
χ^2=	4.99		1.65		2.97	
df=	2		2		2	
P=	0.08		0.44		0.23	

At spawning, 1-30 May:

	1995 Tags		1996 Tags		Both	
	US	DS	US	DS	1995 Tags	1996 Tags
GPR	16	5	7	10	21	17
dnf+other[b]	11	7	7	9	16	17
Died	8	10	8	13	18	21
χ^2=	4.12		0.12		0.68	
df=	2		2		2	
P=	0.13		0.94		0.71	

[a] Areas: GPR = Goodpaster River; Tan1 = the Tanana River from DCR upstream to Billie Creek (river mi 336 – 412); Tan2 = the Tanana River from DCR downstream to Delta River (river mi 336 – 321); Tan3 = the Tanana River from the Delta River downstream to Shaw Creek (river mi 321 – 309), and; Tan4 = the Tanana River from Shaw Creek downstream to Moose Creek (river mi 309 – 239).

[b] dnf+other = Fish not found plus fish found in other areas.

Table 5.-Overwintering locations from December aerial surveys for 55 Arctic grayling implanted with radio transmitters in the DCR in July of 1995 and 1996.

	1995 Tags					1996 Tags				
Location[a]	n	$\hat{p}$	SE	-95CI	+95CI	n	$\hat{p}$	SE	-95CI	+95CI
Tan1	8	0.15	0.05	0.05	0.24	8	0.15	0.05	0.05	0.24
DCR	8	0.15	0.05	0.05	0.24	9	0.16	0.05	0.06	0.26
GPR	19	0.35	0.06	0.22	0.47	11	0.20	0.05	0.09	0.31
Tan2	12	0.22	0.06	0.11	0.33	14	0.25	0.06	0.14	0.37
Tan3	5	0.09	0.04	0.01	0.17	8	0.15	0.05	0.05	0.24
Tan4	2	0.04	0.03	-0.01	0.09	3	0.05	0.03	-0.01	0.12
dnf[b]	1	0.02	0.02	-0.02	0.05	2	0.04	0.03	-0.01	0.09
	55					55				

[a] Location: Tan1 = the Tanana River from DCR upstream to Billie Creek (river mi 336 – 412); Tan2 = the Tanana River from DCR downstream to Delta River (river mi 336 – 321); Tan3 = the Tanana River from the Delta River downstream to Shaw Creek (river mi 321 – 309), and; Tan4 = the Tanana River from Shaw Creek downstream to Moose Creek (river mi 309 – 239).

[b] dnf = did not find. Radio tag was not located during survey.

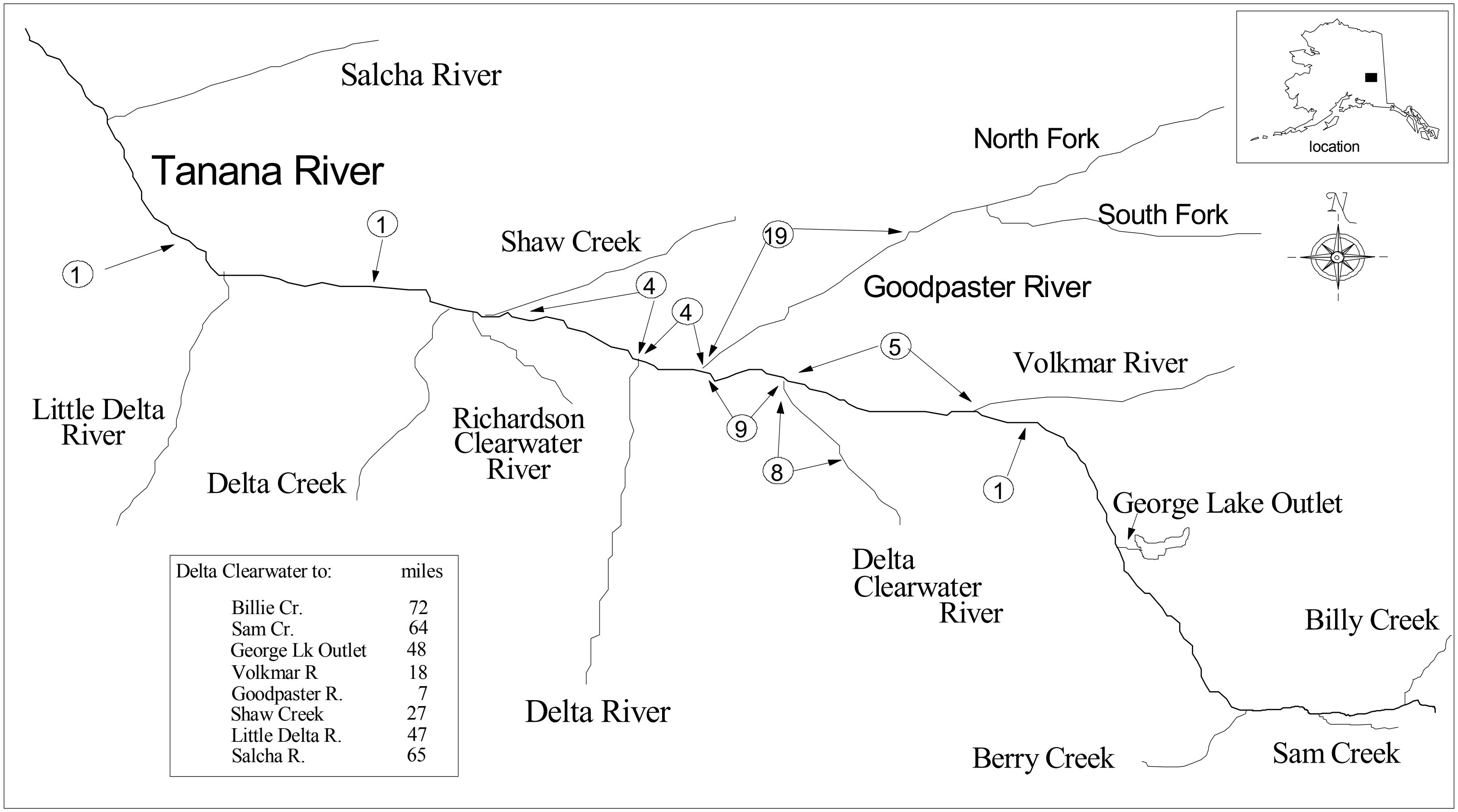

Figure 3.-Overwintering distributions for 55 radio-tagged Arctic grayling released in the Delta Clearwater River in July 1995. Circled numbers depict number of fish within the marked areas.

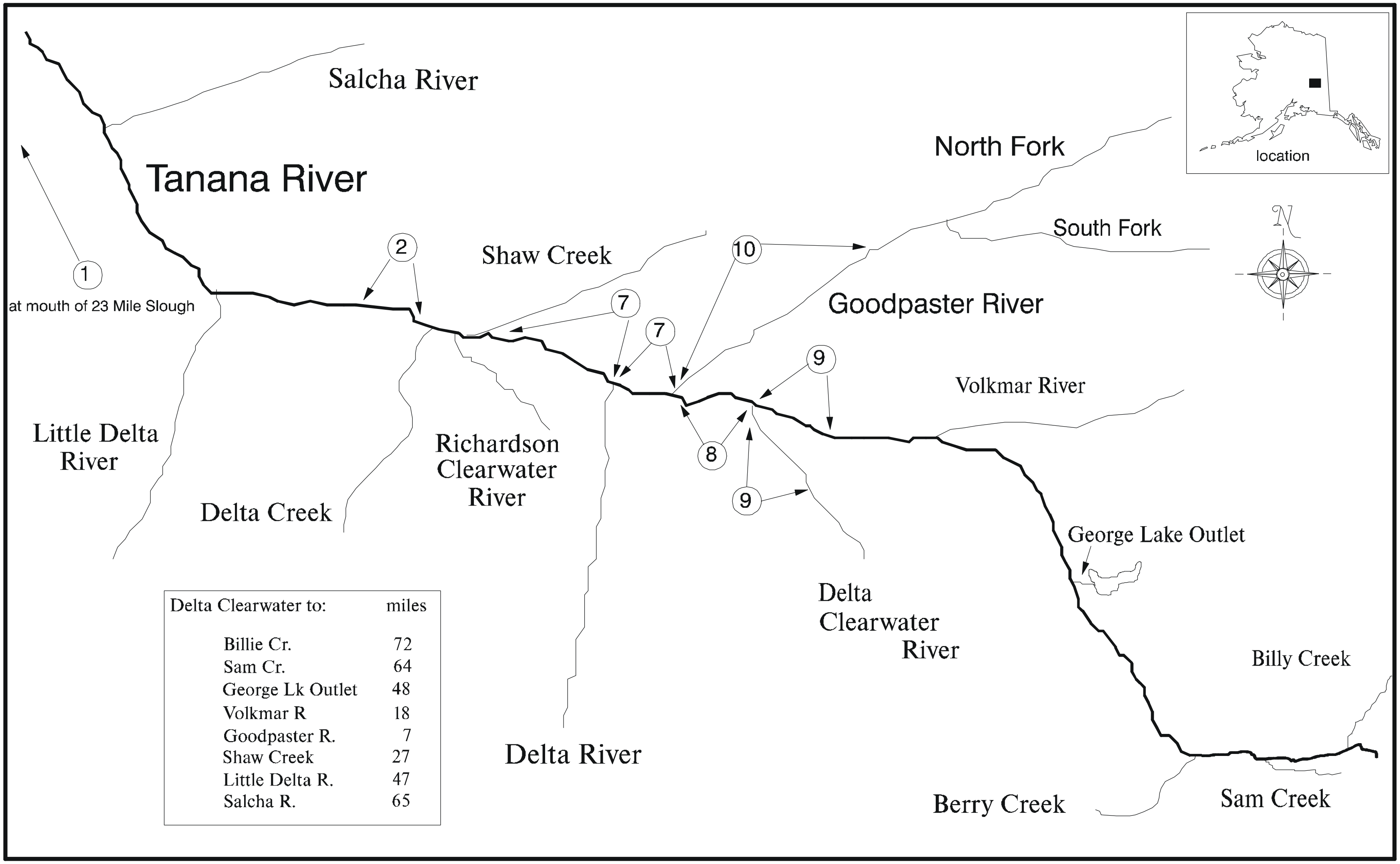

Figure 4.-Overwintering distributions for 55 radio-tagged Arctic grayling released in the Delta Clearwater River in July 1996. Circled numbers depict number of fish within the marked areas.

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overwintering 49% (SE = 7%) and 60% (SE = 7%) of the 1995 and 1996 tag releases, respectively. Five fish located the farthest downstream in the Tanana (below Shaw Creek; Figures 3 and 4) were later determined to be mortalities or tag losses. The Goodpaster River was the next significant area for overwintering with 35% (SE = 6%) and 20% (SE = 5%) of 1995 and 1996 tag releases, respectively, dispersed throughout its lower 20 mi. Approximately 15% (17 fish) of the fish radio-tagged in 1995 and 1996, were still in the DCR in December. Fourteen of these fish were later determined either as mortalities or tag losses with the remaining three fish moving to the Goodpaster River (one fish) and the Volkmar River (two fish) to spawn.

SPAWNING AREAS

Radio tracking surveys located fish in seven tributaries of the Tanana River during spawning (Table 6). Three of these streams (the Goodpaster and Volkmar rivers and Billy Creek) were common to both 1995 and 1996 tag releases. Spawning fish were not expected to be found in the DCR, however one fish from the 1996 tagging group was located in the DCR in May. Unlike the Goodpaster and Volkmar rivers or Shaw Creek, the DCR had never been documented as a spawning area despite numerous studies dating back to 1952 (Ridder 1991). Fish not in spawning tributaries but located in the Tanana and Delta Clearwater rivers are presented in Table 6 as dead because of no movement. There were 11 dead fish in the Tanana River and seven dead fish in the DCR from those tagged in 1995. There were 14 dead fish in the Tanana River and seven dead fish in the DCR from those tagged in 1996. In both years some fish were not located during successive surveys but were later located alive in the DCR. These fish are presented in Table 6 as having spawned in unknown tributaries based on location at their last sighting. One fish may have spawned in Berry Creek. An angler fishing Berry Creek on 4 June was observed by a Department of Fish and Game employee releasing a fish with an obvious antenna (D. Edwards, Alaska Department of Fish and Game, Fairbanks, personal communication). The non-resident angler reported having good success catching and releasing Arctic grayling and thought fish were heading upstream. A ground survey on 6 June of the creek's lower mile and subsequent flight surveys on 12 and 17 June failed to either locate a tag or observe fish. Berry Creek is a short, mountain run-off stream and had a water temperature of 3.9 C° on 6 June. The temperature and anecdotal information indicated the timing was prior to or during the spawning period and thus much later than either the Goodpaster River or Shaw Creek.

Seventeen fish were present in the Goodpaster River on the December and March surveys. Twenty fish were in the Goodpaster River on 9 April and all 21 fish were present on the 29 April-1 May 1996 survey. This contrasts with the other tributaries where fish remained in the Tanana River until break-up.

The proportion of Arctic grayling in spawning streams required adjustments due to mortalities, fish not found, and the finding that fish can be transient in one stream prior to spawning in another. Of 21 fish tagged in 1995 and located in the Goodpaster River during spawning, nine were determined to have died; six of these died before the spawning period (Appendix A3). Of the 17 fish tagged in 1996 and located in the Goodpaster River in May, all had died before spawning (Appendix A3). One fish tagged in 1996 and located in the Volkmar River was determined as dead prior to spawning. Fish that died prior to spawning were not used to estimate spawning proportions.

Table 6.-Results of May spawning surveys for radio implanted Arctic grayling released in the Delta Clearwater River (DCR) in July 1995 and 1996.

	1995 Tags			1996 Tags			Both		
Location	n	$\hat{p}$	SE	n	$\hat{p}$	SE	n	$\hat{p}$	SE
Shaw Cr	1	0.02	0.02	0	0.00	---	1	0.01	0.01
DS Unk	0	0.00	---	1	0.02	0.02	1	0.01	0.01
GPR	21	0.38	0.07	17	0.31	0.06	38	0.35	0.05
DCR	0	0.00	---	1	0.02	0.02	1	0.01	0.01
US Unk	2	0.04	0.03	0	0.00	---	2	0.02	0.01
Volkmar R	1	0.02	0.02	9	0.16	0.05	10	0.09	0.03
George Cr	1	0.02	0.02	0	0.00	---	1	0.01	0.01
Sam Cr	1	0.02	0.02	0	0.00	---	1	0.01	0.01
Billy Cr	1	0.02	0.02	1	0.02	0.02	2	0.02	0.01
dnf[d]	9	0.16	0.05	5	0.09	0.04	14	0.13	0.03
Dead	18	0.33	0.06	21	0.38	0.07	39	0.35	0.05
	55	1.00	---	55	1.00	---	110	1.00	---

a DS Unk = Unknown spawning tributary(s) downstream (DS) of the DCR confluence with the Tanana River.

b GPR = Goodpaster River.

c US Unk = Unknown spawning tributary(s) upstream (US) of the DCR confluence with the Tanana River.

d dnf = did not find. Radio tag was not located during survey.

Of the 44 fish from the 1995 and 1996 tagging groups alive during spawning, the majority, 35 fish (80%, SE = 6%), spawned in the Goodpaster and Volkmar rivers. Six fish were spread among five streams (2% to 5% in each; Table 7) and three fish spawned in unknown streams. The Goodpaster River, the largest drainage represented, also contained the largest proportion (59%, SE = 7%) of spawning fish (Table 7). While the difference in number of spawning fish among tributaries between the two tagging years was not significant (from Table 7, $\chi^2 = 1.19$, df = 1, p = 0.27), the number spawning in the Goodpaster and Volkmar rivers was remarkably different between the two tagging groups: 72% (SE = 10%) of those fish tagged in 1995 spawned in the Goodpaster River versus 50% (SE = 11%) of those tagged in 1996 (Table 7). For the Volkmar River, the difference in percentage of spawning fish between years was larger; 5% (SE = 5%) of those tagged in 1995 versus 36% (SE = 10%) of those tagged in 1996.

Radio-tagged Arctic grayling were found to spawn only in the lower reaches of streams. In the Volkmar River, fish were located between miles 2-10, in Shaw Creek at mile 17, and in the lower 2 mi of the smaller tributaries. The 26 fish in the Goodpaster River were located from mile 2 to mile 29 with 21 fish (81%, SE = 8%) located below mile 12 (Figures 5 and 6).

Rapid dispersal of adult fish after spawning was also apparent in this study. After spawning, all fish of those tagged in 1995 except one (the hypothetical Berry Creek fish) had returned to the DCR by the 28 May survey. Dates of return for those tagged in 1996 were later than for those tagged in 1995, extending from 21 May to 23 June.

FIDELITY TO SUMMER FEEDING AREA

Radio-tagged Arctic grayling exhibited high affinity to home to their summer feeding area. All but one fish of the 40 alive at the end of the surveys, or 98% (SE = 3%), returned to the DCR (Table 8). This one fish spawned in mile 27 of the Goodpaster River then meandered between mile 27 and the lower North and South forks before spending July and August between mile 14-20 of the South Fork.

MORTALITY DETERMINATION

The transmitters of two fish in the Goodpaster River were recovered in the Goodpaster River indicating mortality or tag shedding. Boat surveys of the Goodpaster River failed to find live, large Arctic grayling at the locations, usually near shore area, of the remaining seven transmitters. SLD's of the one fish remaining in the Volkmar River were less than 0.9 mi on three surveys between 1 May and 23 June indicative of a dead fish (Appendix A3). This section of the river during summer contains abundant aquatic vegetation and high water temperatures that is not typical habitat for a 412 mm FL Arctic grayling. Mortality determination for the sole fish remaining in Shaw Creek was more arbitrary. Its transmitter was failing and was located only twice on the five surveys after its last significant movement (Appendix A3). Successive SLD's of 1.2 mi and 0.3 mi was suggestive of mortality but not definitive. However, the fish was most likely dead. Like the Volkmar mortality, the fish was in non-typical habitat for a large Arctic grayling. It remained near the confluence of Caribou Creek from 28 May to 17 June at a time when water temperatures are normally climbing and adult fish are readily moving to summer feeding areas (Ridder 1983, 1985).

Shedding of radio tags was a significant contributor to data loss during the study. Twenty-four recaptures of the radio-tagged Arctic grayling were made in the Goodpaster River during

Table 7.-Number, proportion and 95% confidence intervals of Arctic grayling radio-tagged in 1995 and 1996 in the Delta Clearwater River (DCR) that were located in Tanana River tributaries during spawning in May, 1996 and 1997.

	1995 Tags					1996 Tags					Both				
Location	n	$\hat{p}$	SE	-95CI	+95CI	n	$\hat{p}$	SE	-95CI	+95CI	n	$\hat{p}$	SE	-95CI	+95CI
Shaw Cr	1	0.05	0.05	-0.04	0.13	0	0.00	---	---	---	1	0.02	0.02	-0.02	0.07
DS Unk[a]	0	0.00	---	---	---	1	0.05	0.05	-0.04	0.13	1	0.02	0.02	-0.02	0.07
GPR[b]	15	0.68	0.10	0.48	0.88	11	0.50	0.11	0.29	0.71	26	0.59	0.07	0.44	0.74
DCR	0	0.00	---	---	---	1	0.05	0.05	-0.04	0.13	1	0.02	0.02	-0.02	0.07
US Unk[c]	2	0.09	0.06	-0.03	0.21	0	0.00	---	---	---	2	0.05	0.03	-0.02	0.11
Volkmar R	1	0.05	0.05	-0.04	0.13	8	0.36	0.10	0.16	0.57	9	0.20	0.06	0.08	0.33
George Cr	1	0.05	0.05	-0.04	0.13	0	0.00	---	---	---	1	0.02	0.02	-0.02	0.07
Sam Cr	1	0.05	0.05	-0.04	0.13	0	0.00	---	---	---	1	0.02	0.02	-0.02	0.07
Billy Cr	1	0.05	0.05	-0.04	0.13	1	0.05	0.05	-0.04	0.13	2	0.05	0.03	-0.02	0.11
Subtotal	22	1.00	---	---	---	22	1.00	---	---	---	44	1.00	---	---	---
DS and US Areas Combined:															
DS	1	0.05	0.05	-0.04	0.13	1	0.05	0.05	-0.04	0.13	2	0.05	0.03	-0.02	0.11
GPR	15	0.68	0.10	0.48	0.88	11	0.50	0.11	0.29	0.71	26	0.59	0.07	0.44	0.74
DCR	0	0.00	0.00	0.00	0.00	1	0.05	0.05	-0.04	0.13	1	0.02	0.02	-0.02	0.07
US	6	0.27	0.10	0.08	0.46	9	0.41	0.11	0.20	0.62	15	0.34	0.07	0.20	0.48
	22	1.00	---	---	---	22	1.00	---	---	---	44	1.00	---	---	---

[a] DS Unk = Unknown spawning tributary(s) downstream of the DCR confluence with the Tanana River.

[b] GPR = Goodpaster River.

[c] US Unk = Unknown spawning tributary(s) upstream of the DCR confluence with the Tanana River.

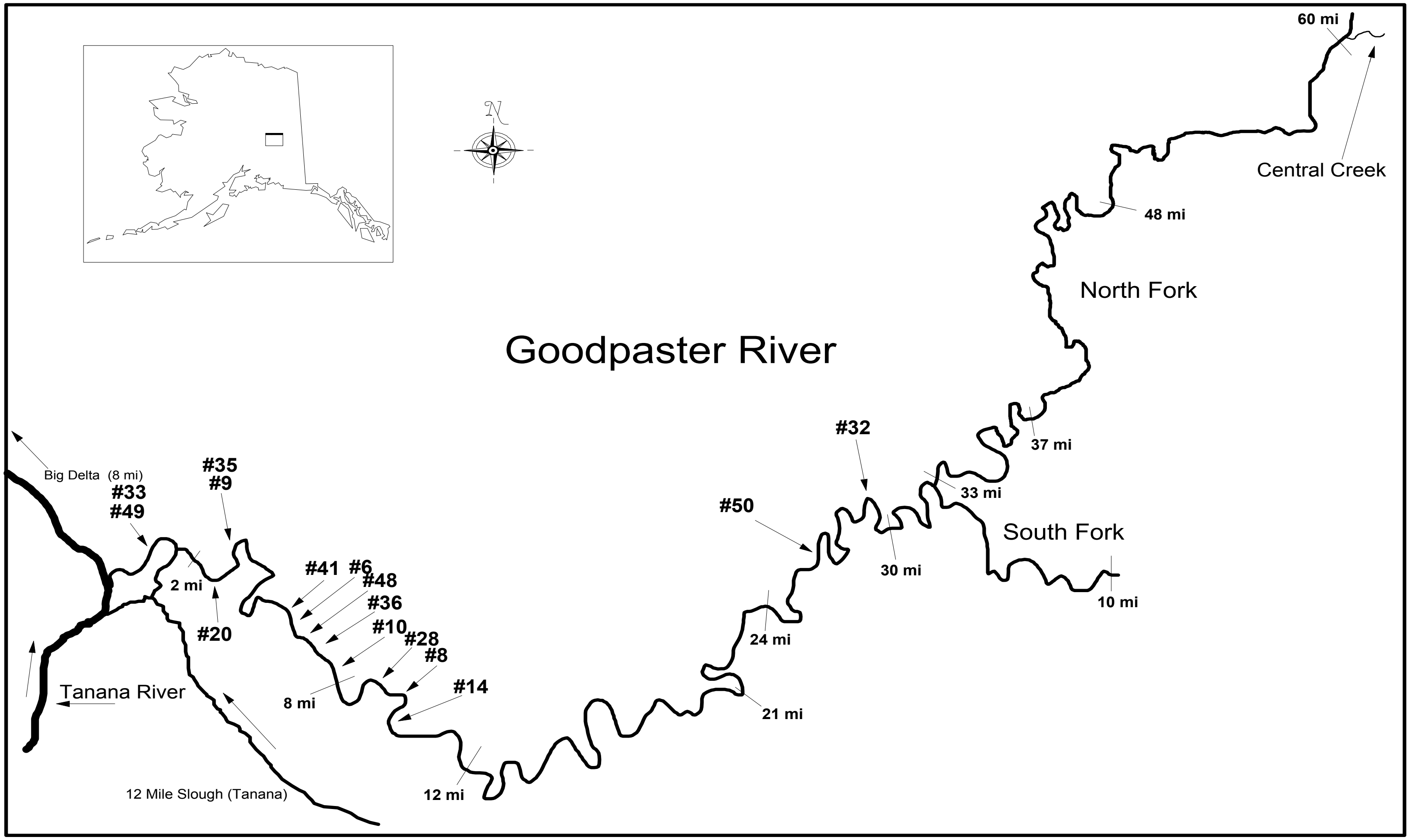

Figure 5.-Locations of 15 Arctic grayling alive at the time of spawning, May 1996 within the Goodpaster river which were radio-tagged in the Delta Clearwater River in July 1995 Numbers refer to individual fish (see Appendix A1).

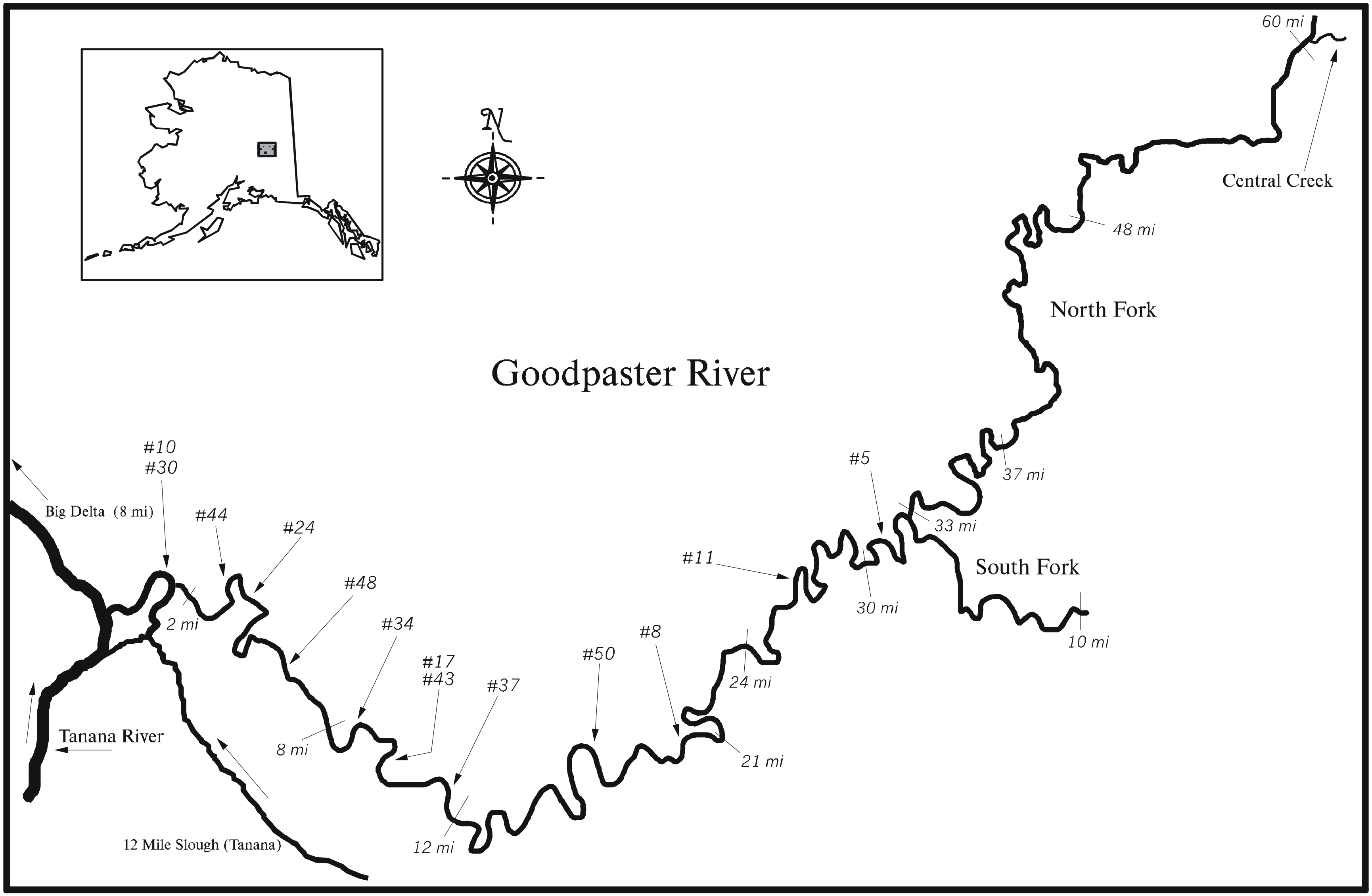

Figure 6.-Locations of 11 Arctic grayling alive at the time of spawning, May 1997 within the Goodpaster River which were radio-tagged in the Delta Clearwater River in July 1996. Numbers refer to individual fish (see Appendix A1).

Table 8.-Percentage of Arctic grayling radio-tagged in 1995 and 1996 by spawning location that returned to the Delta Clearwater River (DCR) the following year.

1995 Radio Tags

Spawning Location	Total Found	Total Live	Return to DCR n	Return to DCR %
Shaw Cr	1	0	0	---
GPR[a]	21	12	11	92%
US Unk[b]	2	2	2	100%
Volkmar R	1	1	1	100%
George Cr	1	1	1	100%
Sam Cr	1	1	1	100%
Billy Cr	1	1	1	100%
Subtotal	28	18	17	94% (SE = 6%)

1996 Radio Tags

Spawning Location	Total Found	Total Live	Return to DCR n	Return to DCR %
DS Unk[c]	1	1	1	100%
GPR	17	11	11	100%
DCR	1	1	1	100%
Volkmar R	9	8	8	100%
Billy Cr	1	1	1	100%
Subtotal	29	22	22	100% (SE = 0%)
Total	57	40	39	98% (SE = 3%)

a GPR = Goodpaster River.

b US Unk = Unknown spawning area upstream of the DCR confluence with the Tanana River.

c DS Unk = Unknown spawning area downstream of the DCR confluence with the Tanana River.

sampling in May 1996 (n = 18) and 1997 (n = 6) and in the DCR in July of 1996 and 1997 (n = 18; Table 9). Six fish had shed their tags for an overall tag shedding rate of 25% (SE = 9%). A distinguishing characteristic of these fish was a visible 2 mm scar in the anterior third of the incision. Most fish with tags had a near indistinguishable scar. A few fish with tags still retained an anterior suture with surrounding inflamed tissue although the incision was healed. It is likely that tags were shed soon after implantation. Of the two fish that shed tags and could be identified from Floy tags, tracking locations showed no movement after the October and December flights.

DISCUSSION

Arctic grayling assemble in the DCR for summer feeding from several spawning stocks. Results from this radio telemetry study have indicated that once large adult Arctic grayling recruit to the DCR, they demonstrate strong fidelity to the DCR. These findings are similar to those of Ridder (1991), who found that post-spawning Arctic grayling migrate to the DCR on an annual basis. For purposes related to using a catch-age approach in assessing the Arctic grayling population in the DCR, it is irrelevant from which spawning stock fish originate from; however, the age at which they recruit is critical to analysis. Clark and Ridder (1994) used anecdotal information and perceptions from prior researchers in suggesting that Arctic grayling recruit to the DCR by age 5. The mechanism of recruitment of post-spawning fish to the DCR is unknown. Because the DCR is a premier feeding location, fish may seek to inhabit its waters; displacement of large fish either through mortality or harvest may then provide opportunities for emmigrating fish to recruit to the DCR. It is assumed that with no exploitation, Arctic grayling in the DCR will achieve some unknown level of carrying capacity, which would then influence the proportion recruiting from various donor or parent stocks.

Radio telemetry data from this study documented seven spawning streams for adult Arctic grayling with anecdotal information adding an eighth stream (Berry Creek). With the majority of fish preferring just two streams (the Goodpaster and Volkmar rivers), the probability of detecting less frequented spawning streams is low. The telemetry failed to identify the Salcha River where DCR summer feeding fish have been documented to spawn (Ridder 1991).

If Arctic grayling home to natal areas as well as to the DCR for summer feeding, then these spawning streams would indeed be 'donor' streams. The ability of Arctic grayling to rapidly colonize new habitat (Fleming 1998), to utilize various habitats at different life stages (Tack 1980) and their ubiquitous distribution within Alaska suggests that homing to a natal area may be less important than homing to good summer feeding habitat.

A significant proportion (80%) of the summer feeders in the DCR spawned in two streams within 18 mi of the mouth of the DCR. The six other spawning streams, five of which were more distant, drew less than 5% of the fish. While these distant spawning streams may be less important to the DCR summer population, it cannot be said that the DCR is less important to the spawning populations. While the Goodpaster River was the spawning site of 59% of the DCR summer population, the DCR fish accounted for only 10% of the Goodpaster River's spawning population (Peckham and Ridder 1979). Smaller streams may contribute a higher percentage of their stock to the DCR than larger streams. If so, exploitation in the DCR fishery would affect populations spawning in smaller streams more than the Goodpaster's spawning population.

Table 9.-Recaptures of radio-tagged Arctic grayling in the Goodpaster (GPR) and Delta Clearwater (DCR) rivers in 1996 and 1997.

Date	Location	Mile	Sex	Length	Tag Number	Tag Color	Tag Year	Shed
05/10/96	GPR	27	M	359	61111	3	1995	No
05/12/96	GPR	12	F	376	61745	3	1995	No
05/12/96	GPR	12	F	442	61763	3	1995	No
05/12/96	GPR	9	M	385	61907	3	1995	No
05/12/96	GPR	9	M	351	61911	3	1995	No
05/11/97	GPR	1	M	412	11490	5	ND[a]	No
07/19/96	DCR	12	---	368	19838	6	1995	No
07/23/96	DCR	12	---	403	19781	6	1995	No
07/24/96	DCR	10	---	418	---	---	1995	No
07/24/96	DCR	10	---	382	---	---	1995	No
07/31/96	DCR	3	---	354	19813	6	1995	No
07/31/96	DCR	3	---	391	---	---	1995	No
07/17/97	DCR	13	F	444	61763	3	1995	No
07/25/97	DCR	5	---	411	19781	6	1995	No
07/19/96	DCR	10	---	400	---	---	1995	Yes
07/23/96	DCR	12	---	415	---	---	1995	Yes
07/24/96	DCR	10	F	392	---	---	1995	Yes
07/24/97	DCR	13	F	395	---	---	1995	Yes
07/17/97	DCR	13	F	386	25555	8	1996	No
07/17/97	DCR	11	F	379	25558	8	1996	No
07/24/97	DCR	13	---	405	25562	8	1996	No
07/25/97	DCR	3	---	411	61956	3	1996	No
07/17/97	DCR	9	M	368	25568	8	1996	Yes
07/24/97	DCR	13	M	372	25594	8	1996	Yes

[a] ND = fish had lost

Management of the DCR or similar mixed-stock fisheries should not focus solely on main contributors but include the smaller ones as well.

The contribution of the Goodpaster River to the DCR found in this study is similar to that found in an earlier study that used discriminate function analysis of scale patterns of age 3 fish. Using a two-way discriminating function with an 85% classification accuracy, Ridder (1983) classified a DCR sample as being comprised of 51% Goodpaster River stock and 49% Volkmar River stock.

Of the eight streams found as spawning areas, the DCR was unexpected but not surprising. Arctic grayling were not thought to spawn in spring-fed systems (Tack 1980). Gravid fish, spawning activity, or young of the year have never been documented within the DCR (Ridder, 1978, 1985 and per observation). As a spring-fed stream, water temperatures are cold: maximum of 8 C° with mean May and June temperatures of 6.3 C° (SD = 1.1 C°) and are not optimum for the rapid hatching essential to the species (Armstrong 1986). However, Arctic grayling are opportunists in selection of spawning areas (Armstrong 1986). The fish in question was a 362 mm FL female (fish ID#53, Appendix A2), most likely mature and thus likely spawned. It is the first documentation of Arctic grayling spawning in or near the DCR. The question then is whether the spawning area was actually in the DCR or nearby. Newly emergent Arctic grayling fry were caught in late May and early June 1998 in an out-migrant trap set in Bluff Cabin Slough, a spring influenced slough of the Tanana River 2 mi downstream of the DCR (J. Finn, United States Biological Survey, personal communication). As in the DCR, these spring influenced sloughs seldom freeze but are typically warmer than the DCR in early spring (Ridder 1981). Eight radio implanted fish in this study were found overwintering in or near the slough. Bluff Cabin Slough's significance to the DCR population is similar to those small spawning tributaries upstream of the DCR (2% SE = 2%; Table 7). Collectively, these small donor stocks are important, contributing 20% to the summer population (SE = 6%; from Table 7).

Non-viable transmitters, whether due to fish mortality, tag failure, or tag shedding, compromised the precision of the study especially in the probability of documenting the minor spawning streams. Sixty percent (n = 66; SE = 5%) of the radio-tagged fish failed to add to spawning documentation while 64% (n = 70; SE = 5%) failed to last through to the study's end. These failure rates are similar to other Arctic grayling telemetry studies (58%, SE = 7% Peckham and Ridder1979; 55% SE = 6%, West et al. 1992). Discounting the failures with the 25% tag shedding rate, failures would have declined to 45% (n = 49) during spawning and 47% (n = 18) for homing. Tag shedding could stem from suture failure due either to too few or improperly tied sutures, the peeling off of tissue adhesive that adhered only to suture knots and not to skin, or encapsulation. Encapsulation of radio tags by the intestine has been found to be the primary mechanism of expulsion in channel catfish (71% rate over 112 d, Summerfelt and Mosier 1984; 19% over 23 d, Marty and Summerfelt 1986) and rainbow trout (59% over 175 d, Chisholm and Hubert 1985). Though it is possible that intestinal encapsulation and expulsion occurred in this study, the unique tag scar and timing of tag losses suggests expulsion through the incision due to failure of anterior sutures. Future telemetry studies in Arctic grayling requiring surgical implantation should carefully consider the potential for a high failure rate by adjusting sample sizes as well as the positioning and number of sutures and the correct application of tissue adhesive.

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APPENDIX A

Appendix A1.-Length, weight, sex, tag information and location of Arctic grayling implanted with radio tags in the Delta Clearwater River, July 1995.

Date	River Mile	Fish ID	Gear	Frequency	Length (mm FL)	Weight (g)	Sex	Age	Floy Tag	Color
7/20/95	12	1	EB	149.602	414	782	F	na	---	---
7/20/95	12	2	EB	149.610	365	555	F	na	---	---
7/20/95	12	3	EB	149.621	361	606	M	na	---	---
7/20/95	12	4	EB	149.631	358	470	F	na	19838	Blue
7/20/95	12	5	EB	149.642	435	995	M	8	---	---
7/20/95	12	6	EB	149.652	394	815	F	11	---	---
7/20/95	12	7	EB	149.661	364	498	F	7	19770	Blue
7/20/95	12	8	EB	149.670	439	1144	F	na	---	---
7/20/95	12	9	EB	149.682	412	990	M	8	---	---
7/20/95	12	10	EB	149.691	374	664	M	8	---	---
7/20/95	12	11	EB	149.703	407	790	M	8	---	---
7/20/95	12	12	EB	149.710	344	595	F	8	---	---
7/20/95	12	13	EB	149.723	365	611	F	6	---	---
7/20/95	12	14	EB	149.730	369	587	M	8	---	---
7/20/95	12	15	EB	149.742	387	757	F	12	---	---
7/20/95	12	16	EB	149.750	411	903	M	11	---	---
7/21/95	5.1	17	H&L	149.760	376	654	F	6	---	---
7/21/95	5.1	18	H&L	149.803	379	610	F	7	---	---
7/21/95	5.1	19	H&L	149.812	360	581	F	7	---	---
7/21/95	5.1	20	H&L	149.822	357	666	F	8	---	---
7/21/95	5.1	21	EB	149.831	349	515	F	6	---	---
7/21/95	5.1	22	EB	149.841	342	ND	F	7	---	---
7/21/95	5.1	23	EB	149.850	397	805	M	8	---	---
7/21/95	5.1	24	H&L	149.861	374	507	M	6	---	---
7/21/95	5.1	25	EB	149.872	371	ND	F	6	19278	Blue
7/21/95	5.1	26	H&L	149.882	384	609	F	7	---	---
7/21/95	5.1	27	EB	149.902	366	505	F	6	---	---
7/21/95	5.1	28	EB	149.910	374	542	F	7	---	---
7/21/95	5.1	29	EB	149.923	432	1,060	M	10	---	---
7/24/95	12	30	EB	149.932	398	737	M	8	---	---
7/24/95	12	31	EB	149.941	373	528	M	8	---	---
7/24/95	12	32	EB	149.951	347	497	F	6	---	---
7/24/95	12	33	EB	149.960	405	847	F	11	---	---
7/24/95	12	34	EB	149.972	347	517	F	6	---	---
7/24/95	12	35	EB	149.981	395	719	M	8	19781	Blue
7/24/95	12	36	EB	149.992	350	548	M	na	---	---
7/24/95	12	37	EB	148.371	379	657	M	7	---	---

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Date	River Mile	Fish ID	Gear	Frequency	Length (mm FL)	Weight (g)	Sex	Age	Floy Tag	Color
7/24/95	12	38	EB	148.453	411	835	F	8	---	---
7/24/95	12	39	EB	148.470	352	565	F	5	---	---
7/24/95	12	40	EB	148.482	354	540	M	6	---	---
7/25/95	3.8	41	H&L	148.502	371	670	F	na	---	---
7/25/95	3.8	42	H&L	148.522	411	784	F	10	---	---
7/25/95	3.8	43	H&L	148.542	353	469	F	6	19527	Blue
7/26/95	4.1	44	H&L	148.562	358	456	M	na	---	---
7/26/95	4.1	45	H&L	148.623	389	630	M	9	---	---
7/26/95	4.1	46	H&L	148.663	438	919	M	12	19954	Blue
7/26/95	4.1	47	H&L	148.681	444	ND	M	8	---	---
7/26/95	4.1	48	H&L	148.702	354	ND	M	8	19813	Blue
7/27/95	5.1	49	H&L	148.722	406	777	F	8	---	---
7/27/95	5.1	50	H&L	148.742	352	571	M	7	---	---
7/27/95	5.1	51	H&L	148.761	397	707	F	8	19682	Blue
7/27/95	5.1	52	H&L	148.781	416	900	M	8	---	---
7/27/95	5.1	53	H&L	148.802	391	731	F	8	---	---
7/27/95	5.1	54	H&L	148.832	365	530	M	na	---	---
7/27/95	5.1	55	H&L	148.912	364	521	F	6	---	---
Totals				Average	381	676				
				STD	28	167				
				Min	342	456				
				Max	444	1,144				

Appendix A2.-Length, weight, sex, tag information and location of Arctic grayling implanted with radio tags in the Delta Clearwater River, July 1996.

Date	River Mile	Fish ID	Frequency	Length (mm FL)	Weight (g)	Sex	Age	Floy Tag	Color
7/27/96	9	1	148.010	370		M	na	19770	Blue
7/24/96	12	2	148.022	434	961	M	na	25550	Gray
7/24/96	12	3	148.032	422	855	F	na	25551	Gray
7/24/96	12	4	148.042	409	702	M	7	25552	Gray
7/24/96	12	5	148.052	387	736	M	9	25553	Gray
7/24/96	12	6	148.062	387	641	M	7	25554	Gray
7/24/96	12	7	148.072	375	578	F	7	25555	Gray
7/24/96	12	8	148.083	400	812	M	10	25556	Gray
7/24/96	12	**9**	148.092	374	565	M	9	25557	Gray
7/24/96	10	10	148.102	412	798	M	na	60630	Gray
7/24/96	10	11	148.112	373	621	F	8	25558	Gray
7/24/96	10	12	148.122	398	699	F	8	25559	Gray
7/24/96	10	13	148.131	397	748	F	6	25560	Gray
7/24/96	10	14	148.143	362	591	F	7	25561	Gray
7/24/96	10	15	148.152	395	758	M	7	25562	Gray
7/24/96	10	16	148.161	391	644	M	8	25563	Gray
7/25/96	7	17	148.171	387	695	M	8	25564	Gray
7/25/96	7	18	148.182	378	603	F	6	25565	Gray
7/25/96	7	19	148.192	354	494	M	6	25566	Gray
7/25/96	7	20	148.202	368	586	M	7	25567	Gray
7/25/96	7	21	148.212	353	465	M	6	25568	Gray
7/25/96	7	22	148.222	373	508	M	6	25569	Gray
7/25/96	7	23	148.233	367	526	F	6	25570	Gray
7/25/96	7	24	148.242	361	568	M	8	51805	Gray
7/25/96	3	25	148.252	438	955	F	na	25571	Gray
7/25/96	3	26	148.261	404	692	M	7	25572	Gray
7/25/96	3	27	148.272	405	878	F	10	25573	Gray
7/25/96	3	28	148.280	383	677	M	8	25574	Gray
7/25/96	3	29	148.291	384	669	M	7	25575	Gray
7/27/96	9	30	148.302	367		M	7	29757	Green
7/25/96	3	31	148.312	378	638	M	8	25576	Gray
7/25/96	3	32	148.323	373	593	F	na	25577	Gray
7/25/96	3	33	148.332	355	489	F	na	25578	Gray
7/25/96	3	34	148.342	385	600	M	na	61798	Gray
7/26/96	1	35	148.351	369	625	M	na	25579	Gray
7/26/96	1	36	148.363	412	751	M	na	25580	Gray
7/26/96	1	37	148.382	409	871	F	na	25581	Gray

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Date	River Mile	Fish ID	Frequency	Length (mm FL)	Weight (g)	Sex	Age	Floy Tag	Color
7/26/96	1	38	148.391	440	849	M	na	25582	Gray
7/26/96	1	39	148.402	385	629	M	na	25583	Gray
7/26/96	1	40	148.411	383	570	M	na	25584	Gray
7/26/96	1	41	148.421	392	651	F	na	25585	Gray
7/26/96	1	42	148.432	369	517	M	na	25586	Gray
7/26/96	1	43	148.442	412	834	M	na	61956	Green
7/26/96	5	44	148.461	387	588	M	na	25587	Gray
7/26/96	5	45	148.511	374	572	M	na	25588	Gray
7/26/96	5	46	148.531	401	806	M	na	25589	Gray
7/26/96	5	47	148.551	390	695	F	na	25590	Gray
7/27/96	9	48	148.571	412	820	M	na	25591	Gray
7/27/96	9	49	148.582	420	806	M	na	25592	Gray
7/27/96	9	50	148.592	410	na	M	na	25593	Gray
7/27/96	9	51	148.603	359	na	M	na	25594	Gray
7/28/96	5	52	148.612	407	772	F	na	25596	Gray
7/28/96	5	53	148.633	362	549	F	na	25595	Gray
7/28/96	5	54	148.642	387	635	F	na	25597	Gray
7/29/96	10	55	149.893	406	733	M	na	25598	Gray
Totals			Average	389	679				
			STD	22	124				
			Min	353	465				
			Max	440	961				

Appendix A3.-Straight line distances (mi) between successive surveys of radio-tagged Arctic grayling remaining in the Goodpaster (GPR) and Volkmar (VR) rivers and Shaw Creek (SC) after spawning. Bold numbers denote last survey in which tag is considered in a live fish.

1995 Tags:

Loc	ID	17-Oct	7-Dec	11-Mar	9-Apr	1-May	6-May	13-May	28-May	11-Jun	17-Jun	3-Jul	5-Jul[a]	16-Jul	15-Aug
GPR	3	8.2	**1.4**	0.8	0.3	0.3	0.0	0.0	0.3	0.6	0.3	0.0	0.0	ns[b]	ns
GPR	5	**7.2**	0.6	1.0	0.7	0.3	0.3	0.3	0.5	0.1	0.3	0.6	0.6	ns	ns
GPR	7	**8.2**	0.3	0.6	0.9	0.9	0.0	0.9	0.6	0.3	0.9	0.9	0.0	0.7	ns
GPR	11	6.0	1.6	3.9	7.9	**5.2**	0.5	0.6	0.4	0.4	0.3	0.8	0.8	0.7	ns
GPR	15	6.3	0.0	0.3	0.7	0.3	1.4	**1.8**	0.3	0.0	0.9	0.6	0.3	0.0	ns
GPR	16	10.8	**1.8**	0.5	0.1	0.5	0.5	0.2	0.1	0.2	0.1	0.0	0.0	ns	ns
GPR	20[d]	8.3	1.6	0.7	0.7	0.4	2.3	**2.8**	0.7	0.6	1.2	1.2	0.7	ns	ns
GPR	33	3.5	**10.5**	0.2	0.1	0.7	0.8	0.6	dnf[c]	1.1	0.8	0.1	0.0	0.3	ns
GPR	41[d]	0.8	7.1	1.8	0.2	0.2	dnf	**2.0**	0.2	0.6	0.6	1.2	0.7	ns	ns
GPR	50	8.9	7.2	0.8	1.4	1.7	1.7	3.2	2.5	0.8	1.2	6.9	ns	2.8	3.4
SC	19	13.4	2.5	6.4	1.7	5.6	5.7	1.7	**6.0**	1.2	0.3	dnf	ns	dnf	dnf

1996 Tags:

Loc	ID	2-Oct	18-Dec	1-May	8-May	21-May	5-Jun	23-Jun	19 Jul[a]
GPR	5	13.7	1.8	**1.4**	ns	0.0	ns	0.3	0.3
GPR	10	7.6	2.8	**3.5**	0.6	0.0	ns	0.3	0.6
GPR	20	**13.0**	0.3	0.3	ns	0.3	ns	1.1	0.9
GPR	27	**8.0**	0.8	0.3	ns	0.3	ns	0.8	0.3
GPR	28	**7.9**	0.3	0.3	ns	0.0	ns	0.0	0.0
GPR	46	**6.3**	0.8	0.0	ns	0.8	ns	0.8	0.0
VR	36	0.3	0.8	**12.9**	0.9	0.6	ns	0.3	ns

[a] This was a boat survey of the lower 32 miles of the Goodpaster River to assist in determinations of mortality. Tags #20 and #41 were found on shore.

[b] ns = tag not included in survey.

[c] dnf = Tag not found during survey.

[d] Radio transmitter recovered on 5 July.